Rice Biotechnology: Helping or Hurting Farmers in the Philippines

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Abstract

Rice is a staple crop in developing countries in Asia. By examining resource-poor and smallholder rice farmers in the Philippines, this article studies the impact of rice biotechnology, by analyzing if adoption of hybrid rice varieties results in improved farmer conditions. Using a propensity score matching approach, the analysis compares the differences in total production between adopters of hybrid seed and non-adopters, while accounting for self-selection bias and the possibility of endogenous factors. From this analysis, it is not clear if rice farmers benefit from hybrid rice seed adoption, as there is a consistent change of sign in farmer benefits between seasons. In the wet season, there is a negative difference in total rice production between adopters of hybrid seed and non-adopters; whereas in the dry season, this difference is positive. Future studies examining farmer benefits of technological adoption should employ a matching approach to correctly compare the effects on adopters and non-adopters.

Many estimates have shown that population increases over the coming decades will lead to a substantial increase in food demand, with estimated increases of 50-100% by 2050 (Royal Society 2009; FAO 2013; Godfray et al. 2010a). Huge gains in technology since the dawn of the Green Revolution in the 1960s have made substantial impacts on global food supply. Through high yielding varieties and an increase in available inputs such as fertilizer and mechanization, crop yields in developing countries have increased 86% since the Green Revolution, compared with 19.5 to 23.5% lower yield rates had technological change not been adopted (Evenson and Gollin 2003). Currently, adoption of biotechnology such as second-generation hybrid or genetically modified crops may have positive effects on yields, farmer income, and contribute to poverty reduction.

Motivation

This article focuses on the involvement of biotechnology in agricultural production systems in developing countries, and the subsequent effects on resource-poor and smallholder farmers, as these individuals have the largest potential to gain from further technological advances in agriculture. By examining resource-poor and smallholder rice farmers in the Philippines, this article will see if biotechnological adoption of hybrid rice varieties results in improved farmer conditions. Further, by looking at characteristics of farmers who adopt technology, it can be possible to distinguish what factors influence adoption of technology and its effect on smallholder farmers. Most importantly, this article will examine the effect of the adoption decision on overall poverty reduction through productivity gains, as measured by improved yields. For the purposes of this article, rice biotechnology will refer to any technology or rice cultivar that has experienced the application of scientific information and methods including cross-breeding, transgenics, cisgenics, and other genetic modification techniques (Juma and Gordon 2014; McAllister, C. H., personal communication, February 17, 2015). Looking at hybrid rice crops in developing countries in Southeast Asia, with a focus on the Philippines, this article will examine the adoption choice of farmers to grow hybrid rice with the objective of generating empirical evidence of economic benefits of adoption.

Background

High yielding varieties (HYV) first seen as a result of the Green Revolution aim to increase yields as a means to combat hunger. Severe famines in the 1950s and 1960s in Asia spurred much of the research towards HYV, and the adoption of this modern variety (MV) crop (IFPRI 2002). The Green Revolution also provided many of Southeast Asia's poor with improved incomes, which in combination with reduced food prices, allowed for a more diverse diet and more calories to consume (IFPRI 2002). However, an unexploited yield gap of 1-2 t/ha (tonnes per hectare) still persists in most rice growing areas of Asia (IRRI 2008). Currently, second-generation hybrid rice varieties and other biotechnological advances are becoming available to farmers, which may play a further role in the reduction of this yield gap and reduce poverty experienced by many smallholders in the Philippines and other rice growing areas of Asia. New rice varieties in the technological pipeline include transgenic varieties with abiotic stress resistance, such as drought, flood, or salinity tolerance, in addition to high yielding hybrid varieties.

Rice is a staple food in Asia, accounting for more than 40% of calories consumed (IRRI 2008). In the Philippines, around 44% of all calories consumed are from rice (FAOSTAT; IRRI). Further, rice in the Philippines is not an inferior good (Jamora et al. 2010). This suggests that rice consumption does not follow Bennett's Law – as income rises from very low levels, consumption of starchy foods do not, in fact, decline. Jamora et al. also estimate that per capita consumption of rice in Asian countries will continue to rise regardless of rises in income or in price (2010). This further implies that rice is fairly price inelastic. According to a 2008 report by International Rice Research Institute (IRRI), the need for rice farmers to improve their livelihood requires productivity gains that are profitable, resource efficient, and sustainable, that also provide a balance between low retail prices for poor consumers and acceptable producer prices.

Literature Review

Several studies have examined the impact that improvements in rice biotechnology have had on farmers in developing countries, including the Philippines. Improvements in production, as measured by yield increases, have been observed in many new rice varieties including both hybrid and genetically modified cultivars. Analyzing 2002 wet season data, Bordey et al. found average hybrid yield to be 10% greater than conventional yields (2004). New abiotic stress tolerant rice varieties have the potential for an average 1 t/ha yield advantage under the specific abiotic stress (Mottaleb et al. 2012; Yorobe Jr. et al. 2014).

In the ex ante economic impact analysis by Mottaleb et al., both producer and consumer welfare were forecasted to benefit from the adoption of abiotic stress tolerant rice varieties in South Asia (2012). Bayer et al. estimate that adoption of Bt rice (a pest-resistant genetically modified (GM) rice) will lead to a significant increase in producer welfare, yet no benefit to consumers (2010). However, Durand-Morat et al. estimate that both producer and consumer welfare will improve with the adoption of Bt rice, with decreases in consumer prices estimated at 4.1% (2015). From this, it is clear that farmers are expected to benefit from rice biotechnology, and that at worst consumer welfare will remain the same. However, improved production and estimated increases in supply through the adoption of biotechnology may also lead to lower prices resulting in a more affordable commodity for people in the Philippines (Mottaleb et al. 2012; Durand-Morat et al. 2015).

There are many factors influencing adoption rates, however farmers may be motivated by the potential to have lower input costs through the adoption of varieties such as stress tolerant rice that does not require excess chemical inputs such as pesticides and fertilizers (Park et al. 2011). In some cases, the reduction in input expenditure mitigates the addition seed cost, resulting in maintained or improved margins (Qaim 2005 in Park et al. 2011). There are also indirect health benefits of adoption of rice biotechnology. This includes the reduction of the handling and use of chemical inputs such as pesticides and fertilizers (Juma and Gordon 2014; Park et al. 2011). Environmental concerns have also generated demand for input efficient technologies (Pingali et al. 2011). Pest-resistant rice and other GM rice cultivars have contributed to the decreased use of chemical inputs, resulting in a reduced environmental impact of agriculture on surrounding ecosystems and watersheds (Juma and Gordon 2014). In light of ever more challenging growing conditions, less land availability, and stronger abiotic stresses due to a changing climate, the availability of hybrid and GM rice alternatives with the ability to cope with these aggravated stresses will be helpful in minimizing potential yield losses (Mottaleb et al. 2012).

Some new rice varieties provide positive net farm income in the presence of abiotic stress (Yorobe Jr. et al. 2014). Abiotic stress tolerance to flooding is an example of a beneficial biotechnology that helps improve farmers incomes by reducing, and in some cases, completely negating the potential risk of crop loss due to flooding in wet season (Cabanilla, 2007; Mottaleb et al., 2012). In general, abiotic stress tolerant rice can be seen as loss-mitigating varieties rather than yield increasing varieties (Mottaleb et al. 2012). The stabilization of production risk is a defining aspect of abiotic stress tolerant varieties, as farmers tend to be risk adverse and therefore more willing to use technology that will mitigate losses. As found in Park et al., increases to farmer income from the adoption of GM crops can have a direct impact on improving quality of life and alleviating poverty (2011). Hybrid rice and other rice biotechnology innovations may act as a type of risk reduction insurance since farmer incomes can be improved through the control of crop losses caused by pests or abiotic stresses such as flooding (Park et al. 2011).

Data

This analysis employs data from the 2005-2006 "Socio-economic Survey of Hybrid Rice Cultivation in the Philippines" accessed from the IRRI Dataverse (Cabrera 2014). This dataset was chosen for its clarity on identifying hybrid and conventional rice varieties, which enables this article to compare the yield and productivity gains between the cultivation of the two variety types. The dataset consists of panel data from two different growing seasons in the same year period, the wet season of 2005 and the dry season of 2006. In this analysis, wet and dry season seed choice will be estimated separately, but the seed choice decision is assumed to be continuous. The dataset focuses on household, farmer, farm, and seed characteristics. From the 128 observations in this dataset, this article's analysis looks at several variables that identify demographic information, farm characteristics and seed choices. Table 1 summarizes the descriptive statistics for the variables used in this analysis.

Demographics are captured by several variables including the number of members of a household, the amount of non-rice income, the age of the farmer, and the education level of the farmer. Pinagli et al. have shown farmer education to have a positive and significant effect on preferring high yielding crop technology in the Philippines (2001). Land tenure is also considered, due to the possibility of insecure land rights influencing the choice of hybrid seed adoption, as proposed by Godfrey et al. (2010a). Land tenure for this dataset ranges from land owned by household, land held as part of a community land trust (CLT) agreement, shared tenancy, fixed rent of land, or mortgaged-in land. Village location is also taken into consideration as variations in land elevation and soil quality need to be accounted for. As well, village location can identify community leaders and possible group choice decisions as community leaders may be more interested in higher yielding technologies and have a strong influence over decision making in their community (Chong 2003). Seed costs are also considered, yet may not be very informative. This is because some hybrid seed may not be bought, but provided through social policies such as subsidy programs and the involvement of public research institutions such as the IRRI. As well, adoption of hybrid rice depends on seed availability (Corales et al. 2006). In previous growing seasons, farmers may have wanted to grow hybrid rice, but the market lacked supply of hybrid seed. Hybrid seed availability is an important variable to include in this analysis.

It is also important to consider non-rice income, as some farmers and households do not use farming as their primary occupation. This variable encompasses any impact of non-rice income from off-farm employment or other crop production. Total income is not encouraged as a measure of productivity gains from seed choice, as it may result in a biased conclusion. Total rice production in kilograms is a more accurate measure of productivity gains due to seed choice, since income may be under-representative of farmer benefits. Using total rice production as a measure captures the possibility that farmers may not sell all that they produce, keeping some for seed or household consumption, or using some of the harvest to trade for needed goods and services. For a summary of the descriptive statistics of the variables used in this analysis, see table 1.

This dataset contains a limited number of observations, n = 128. As such, the analysis was limited by how many variables could be included in order to preserve degrees of freedom. Since this dataset consists of panel data from two different growing seasons in the same year period, the analysis would be improved if the dataset included multiple year and growing season observations (such as wet and dry seasons of both 2005 and 2006), or if there were an increase in the number of observations, such as more farms included in the sample.

It is also important to keep in mind the possibility for some factors to be endogenous. Intrinsically better farmers are more likely to try a new technology because they are more apt to have superior managerial abilities and better access to extension information and services (Yorobe Jr. et al. 2014). These farmers will typically have higher yields than the average rice farmer regardless if they use new technology or not, due to their superior farm management and production skills. More proficient farmers may also exhibit a strong selection bias that influences the adoption decision and effects farmer benefits. By using a propensity score matching approach, the analysis controls for this potential bias.

Approach

From the literature, it is clear that in order to properly estimate whether, and to what extent, adopters and non-adopters differ in total rice production, an adequate analytical method is required to properly analyze the impact of hybrid seed choice on farmer benefits. Since self-selection bias could play a significant factor in the outcome of analyzing hybrid seed choice and farmer benefits in this analysis, a matching approach such as propensity score matching (PSM) should be used. A PSM model estimates the treatment effects of an intervention, which in this article refers to the choice of hybrid over conventional seed. As such, the PSM model captures the differences in total rice production between those who adopted hybrid seed and those who did not. The assessment of yield and income effects of new rice varieties using a difference-in-difference fixed effects regression model by Yorobe Jr. et al. is an excellent baseline for the necessity of a matching approach (2014).

The approach employed in this article entails two analytical steps. First, a probit model is used to estimate the factors that may affect the probability of individual farmer adopting a hybrid seed variety in each season. The treatment selection model can be described by:

(1) Growing hybrid seed in wet season= f(hhsize, hhage, hhedu, hhoccu, village, tenure, cost of seed, availability of hybrid seed, total non-rice income)

(2) Growing hybrid seed in dry season = f(hhsize, hhage, hhedu, hhocc, village, tenure, cost of seed, availability of hybrid seed, total non-rice income)

where growing hybrid seed is the binary dependent variable in both wet and dry season. The purpose of the probit model is to match adopters and non-adopters on covariates so they are directly comparable. Second, by matching treated and non-treated groups (those that grew hybrid seed, and those that grew conventional), we look at the impact of the hybrid rice choice on total rice production (kg) in each season. This step estimates whether significant differences exist between the matched individuals in regards to the outcome variable, in this case total rice production. The matching techniques employed in this approach are the common matching algorithms of Nearest-Neighbour, LLR, Radius, and Kernel.

Results and Discussion

Based on the literature, we hypothesized for the probit model that farmers who adopt hybrid seed in either season may be better educated, have more secure land tenure, have access to readily available hybrid seed, as well as their village location playing a significant positive role in hybrid seed choice (Pingali et al. 2001; Godfrey et al. 2010a; Corales et al. 2006; Chong 2003). Further, for the PSM approach, we hypothesized that adopters of hybrid rice may have higher total rice production outcomes than non-adopters (Bordey et al. 2004; Mottaleb et al. 2012; Yorobe Jr. et al. 2014).

The results from the probit model used to estimate treatment selection are summarized in table 2. In the wet season, village location and hybrid seed availability play a positive and significant role, as predicted. Farmer education variable has a negative coefficient, which is not consistent with the literature. Land tenure variable is positive as predicted. Farmer occupation has a negative coefficient, implying that being a rice grower whose occupation is farming will have a negative impact on hybrid seed choice. Total non-rice income, household size, farmer age variables are all positive.

In the dry season, farmer occupation and total non-rice income play significant negative roles on hybrid seed choice. A negative coefficient for the farmer occupation variable implies that hybrid seed choice is negatively impacted when the rice grower's occupation is farming, compared to when the rice grower's occupation is non-farming. Seed cost and hybrid seed availability in the dry season have positive significant impacts on choosing to grow hybrid rice varieties. This may indicate that farmers have a greater willingness to pay a higher price for seed if they have witnessed its superior agronomic performance (Bordey et al. 2004). Hybrid seeds are often more expensive and less accessible than conventional seed due to intellectual property rights (IPR), as most biotechnology research is conducted by private institutions (Godfray et al. 2010b; Piesse and Thirtle 2010). However, the magnitude of the coefficients of total non-rice income and seed cost are relatively small so their significance may be negligible. Household size and farmer age variables are positive. Farmer education variable has a negative coefficient, which is consistent with the results from the wet season choice model. Village location variable and land tenure are both negative, which contradicts our prediction.

Through the PSM approach and employing common matching algorithms, differences between treatment (hybrid growing) and untreated (conventional growing) groups show variations between seasons, as summarized in table 3. In the wet growing season, there is a negative difference in total production between the treatment group, farmers who grew hybrid rice, and the untreated group, those that grew conventional rice. In the dry growing season, this difference is positive. This implies that farmers who choose hybrid varieties in the dry season will see an increase in total production (kg), whereas those who choose hybrid varieties in the wet season will see a decrease in total production (kg) compared with non-adopters. There are many factors that could influence this change in sign between seasons. The wet season was the first season during which data was collected, followed by the dry season. It is possible that technological adoption advanced between seasons. As well, we see that village location plays a highly significant role in wet season hybrid choice. This may imply the significance of community leaders and social groups in technological adoption.

Factors previously discussed in the literature, such as farmer's education levels, are not found to play significant roles in hybrid choice in either season. Unlike previous studies which show farmer education to have a strong impact on hybrid adoption choice (see Pingali et al. 2001; Bordey et al. 2004; Yorobe Jr. et al. 2014), education is not a significant factor in this matching exercise.

Farming or off-farm occupation also influences total rice production, with smallholders who hold exclusively farming occupations to have a significant negative impact on their overall rice production. This could be due to the fact that farmers who have off-farm occupations and incomes being more willing to try new technologies, however their motivations may be one of a willingness to harbour the risk of new hybrid varieties, or alternatively, as a type of risk reduction insurance, as discussed by Park et al. (2011). It can be inferred that those farm households with higher non-rice incomes (income from other crops, or off-farm income) may be more willing to grow hybrid rice varieties in the wet growing season. However, total non-rice income in the dry season has a significant dampening effect on the probability of hybrid seed choice.

While the differences between the groups are generally not significant, the change of sign between growing seasons is consistent (see table 3). There is a clear distinction between adopters and non-adopters of hybrid rice seed in terms of total rice production. However, as previously discussed, there are limitations to the dataset used in this analysis. By using a PSM approach with more data, or better quality data, it would be interesting to see if the differences between adopters and non-adopters and the overall impact on farmer benefits become significant, and whether the change in sign remains consistent. A PSM approach is necessary to perform this type of analysis as it is possible to reach very different conclusions using an OLS regression approach with the adoption decision as an explanatory variable and an outcome variable of total rice production. This alternative approach could produce divergent results and potentially lead to biased conclusions with incorrect policy implications. For a full summary of why an OLS regression model is a naïve approach when comparing treated and untreated groups, see appendix. In short, by including seed choice as an explanatory variable for total rice production, an OLS regression model does not account for the endogenous nature of seed choice, or for self-selection bias. It is important to use a PSM approach to properly measure and understand the adoption decision and the impact of hybrid seed on total rice production, in order to fully realize the potential of such a technology on farmer benefits, food security, and poverty reduction.

Conclusions

The objective of this article was to analyze the impact of biotechnological adoption on farmer benefits. By looking at adopters and non-adopters of hybrid rice crops, we were able to generate empirical economic evidence of the impact of the adoption decision on total rice production. Utilizing a matching approach with two analytical steps, we employed a probit model to estimate the probability of hybrid seed choice, followed by a propensity score matching (PSM) model with several common matching algorithms to analyze the impact of this decision on total rice production. By matching treated and untreated groups of individuals, we were able to account for self-selection bias and the possibility of endogenous factors. We found a consistent change of sign in the value of total rice production between adopters and non-adopters in different seasons. However, it is not clear if farmers benefit from the technological adoption of hybrid rice.

Future studies employing better quality data with more observations are needed to further investigate the economic benefits to farmers, and the differences in welfare between adopters and non-adopters. It is also necessary that future studies use total rice production as a measure of outcome. Many studies look at income as a measure of improved life quality, but it is a poor metric to use. Total rice production is a much better indicator as it captures the possibility that farmers may not sell all that they produce, keeping some for seed or household consumption, or using some of the harvest to trade for needed goods and services. As a result, future studies should regularly include yield or total production as an indicator of welfare rather than income.

To conclude, it is not clear whether farmers in the Philippines benefit from hybrid seed adoption, as the results from this analysis differ between seasons. Due to limitations of the data used in this article, it is unclear if the change of sign in the differences in total production between adopters and non-adopters is a trend that will continue, or if it is solely seasonally dependent. Further studies should explore the relationship between farmer benefits, and differences between adopters and non-adopters with better and more data, in order to fully understand the impact of hybrid seed adoption choice on farmer benefits.

Tables

Table 2. Propensity Score Function, Wet Season Hybrid Seed Choice

Variable	Coefficient	SE
constant	-1.828	1.136
hhsize	0.035	0.074
hhage	3.35E-04	0.012
hhedu	-0.030	0.048
hhocc	-0.456	0.397
village	0.381***	0.107
tenure	0.003	0.119
wseedc	7.16E-05	4.41E-05
whyavail	2.683***	0.421
totnrinc	2.03E-06	1.34E-06

Observations, n=128
Log-likelihood=-47.304
Pseudo R2=0.466

Propensity Score Function, Dry Season Hybrid Seed Choice

Variable	Coefficient	SE
constant	0.755	1.410
hhsize	0.142	0.107
hhage	0.009	0.016
hhedu	-0.081	0.062
hhocc	-1.023**	0.510
village	-0.106	0.109
tenure	-0.068	0.147
dseedc	4.26E-04***	1.17E-04
dhyavail	1.849***	0.442
totnrinc	-1.08E-05***	3.06E-06

Observations, n=128
Log-likelihood=-34.211
Pseudo R2=0.525

Note: * denotes significance at 10% level, ** 5% significance level, *** 1% significance level

Table 3. Relationship between Adopters and Non-Adopters

Matching Algorithm	Coefficient	SE
Total Production (kg) in Wet Season		
Nearest Neighbour	-7011.579	10590.602
LLR	-18137.882	12645.423
Radius (r=0.01)	-9668.370	11223.942
Radius (r=0.1)	-10452.089*	6281.968
Kernel	-10463.394	7128.121
Total Production (kg) in Dry Season		
Nearest Neighbour	6280.575	8028.257
LLR	6849.653	9109.207
Radius (r=0.01)	6866.947*	4151.332
Radius (r=0.1)	6473.510	6275.239
Kernel	6602.240	7286.035

Note: * denotes significance at 10% level, ** 5% significance level, *** 1% significance level

Table 4. OLS Regression, Total Rice Production (kg)

OLS Regression, Wet Season Total Rice Production (kg)

Variable	Coefficient	SE
constant	-704.521	11346.300
hybrid_w	-5486.650	4268.489
hhsize	146.112	786.738
hhedu	292.835	520.904
hhage	282.702**	122.072
hhocc	-9014.619*	4595.166
village	763.025	961.361
tenure	-374.957	1225.250
wseedc	0.330	0.210
whyavail	1812.573	4429.573
totnrinc	0.042***	0.011

Observations, n=128
R-squared=0.310

OLS Regression, Dry Season Total Rice Production (kg)

Variable	Coefficient	SE
Constant	-2837.150	5690.576
hybrid_d	2567.526	2101.704
hhsize	-108.710	362.114
hhedu	408.174*	239.734
hhage	103.584*	56.802
hhocc	-1335.375	2086.838
village	94.647	462.623
tenure	-1007.587*	566.532
dseedc	1.786***	0.168
dhyavail	2183.144	1824.951
totnrinc	0.027***	0.006

Observations, n=128
R-squared=0.797

Note: * denotes significance at 10% level, ** 5% significance level, *** 1% significance level

References

Bayer, J. C., G. W. Norton and J. B. Falck-Zepeda. “Cost of Compliance with Biotechnology Regulation in the Philippines: Implications for Developing Countries.” AgBioForum 13(1) (2010): 53-62.

Bordey, F. H., J. M. Cabling, C. B. Casiwan, R. G. Manalili, A. B. Mataia and G. O. Redondo. “Socioeconomic Evaluation of Hybrid Rice Production in the Philippines.” Prepared for presentation at the 4th International Crop Science Congress. Brisbane, Austrailia, September 26 – October 1, 2004.

Cabanilla, L. S. “Socio-Economic and Political Concerns for GM Foods and Biotechnology Adoption in the Philippines.” AgBioForum, 10(3) (2007): 178-183.

Cabrera, Ellanie. "Socio-Economic Evaluation of Hybrid Rice Cultivation in the Philippines.” 2008. Harvard Dataverse, V1. DOI: 10.7910/DVN/26246

Chong, M. “Acceptance of Golden Rice in the Philippine ‘rice bowl’”. Nature Biotechnology 21(9) (2003): 971-972.

Corales, A. M., K. Barroga, J. B. Agliam and P. S. Coloma. “Hybrid Rice Promotion in Neuva Ecija: Strategic Partnerships & Innovative Media.” Philippine Journal of Crop Science 31(1) (2006): 3-10.

Durand-Morat, A., E. C. Chavez and E. J. Wailes. “GM rice commercialization and its impact on the global rice economy.” Selected Paper prepared for presentation at the SAEA 2015 Annual Meeting. Atlanta, Georgia, February 2-3, 2015.

Evenson, R. E. and D. Gollin. “Assessing the Impact of the Green Revolution, 1960 to 2000.” Science 300(2003): 758. DOI: 10.1126/science.1078710

Food and Agriculture Organization of the United Nations (FAO). “State of Food and Agriculture 2013.” Rome: FAO, 2013.

Food and Agriculture Organization of the United Nations – Statistics Division (FAOSTAT). “Food Balance.” http://faostat3.fao.org/browse/FB/*/E (accessed March 26, 2015).

Godfray, H. C. J., J. R. Beddington, I. R. Crute, L. Haddad, D. Lawrence, J. F. Muir, J. Pretty, S. Robinson, S. M. Thomas and C. Toulmin. “Food Security: The Challenge of Feeding 9 Billion People.” Science 327(2010a): 812. DOI: 10.1126/science.1185383

Godfray, H. C. J., I. R. Crute, L. Haddad, D. Lawrence, J. F. Muir, N. Nisbett, J. Pretty, S. Robinson, C. Toulmin and R. Whiteley. “The future of the global food system.” Phil. Trans. R. Soc. B. 365(2010b). DOI: 10.1098/rstb.2010.0180

International Food Policy Research Institute (IFPRI). “Green Revolution: Curse or Blessing?” Washington, DC: IFPRI. 2002.

International Rice Research Institute (IRRI). “Responding to the Rice Crisis: How IRRI Can Work With Its Partners.” Metro Manila, Philippines, 2008.

International Rice Research Institute (IRRI). “World Rice Statistics Online Query Facility.” http://ricestat.irri.org:8080/wrs (accessed March 26, 2015).

Jamora, N., H. G. Valera, I. Molina, M. J. Matriz and S. Mohanty. “Can we keep up with the demand? Emerging trends in global rice consumption.” Poster presented at Agricultural and Applied Economics Association’s 2010 AAEA, CAES & WAEA Joint Annual Meeting. Denver, CO. July 25-27, 2010.

Juma, C., and C. Gordon. “Transgenic Crops and Food Security.” Plant Biotechnology (2014). DOI: 10.1007/978-3-319-06892-3__5

McAllister, C. H. “Analysis of the biochemical and genetic properties of alanine aminotransferase enzymes.” PhD. diss., University of Alberta, 2014.

Mottaleb, K. A., R. M. Rejesus, S. Mohanty, M. V. R. Murty, T. Li, H. G. Valera and M. K. Gumma. “Ex Ante Impact Assessment of a Drought Tolerant Rice Variety in the Presence of Climate Change.” Selected Paper prepared for presentation at the Agricultural & Applied Economics Association’s

2012 AAEA Annual Meeting. Seattle, Washington, August 12-14, 2012.

Park, J. R., I. McFarlane, R. H. Phipps & G. Ceddia. "The role of transgenic crops in sustainable development." Plant Biotechnology Journal 9(2011): 2-21.

Piesse, J., and C. Thirtle. "Agriculture R&D, technology, and productivity." Phil. Trans. R. Soc. B. 365(2010): 3035–3047. DOI: 10.1098/rstb.2010.0140

Pingali, P. L., S. D. Rozelle and R. V. Gerpacio. "The Farmer's Voice in Priority Setting: A Cross-Country Experiment in Eliciting Technological Preference." Economic Development and Cultural Change 49(3) (2001): 591-609. DOI: 10.1086/452517

Royal Society. "Reaping the Benefits: science and the sustainable intensification of global agriculture." London, UK: Royal Society (2009).

Yorobe Jr., J. M., V. O. Pede, R. M. Rejesus, O. P. Velarde, H. Wang and J. Ali. "Yield and Income Effects of the Green Super Rice (GSR) Varieties: Evidence from a Fixed-Effects Model in the Philippines." Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting. Minneapolis, MN, July 27-29, 2014.

Appendix

A Naïve Analysis – OLS Approach

By using an OLS regression approach, we can look at the total rice production outcome of choosing to grow hybrid seed:

(1) Total rice production (kg) = f(hybrid seed choice, hhsize, hhedu, hhage, hhocc, village, tenure, seed cost, hybrid seed availability, total non-rice income)

where total rice production is a continuous variable expressed in kilograms. The results from the OLS regression can be found summarized in table 4.

In the wet season, farmer age and total non-rice income have significant positive effects on total rice production, whereas farmer occupation has a significant negative impact on total rice production. The coefficients on some variables change sign from the matching approach to the OLS regression approach. For example, the coefficient on the farmer education variable is now positive and land tenure variable is now negative.

In the dry season, farmer education and age have significant and positive roles in total rice production. The fact that farmer education is positive and significant corresponds with the literature. Seed cost and total non-rice income are also positive and significant, whereas land tenure has a significant negative impact on total rice production. Again, the coefficients on some variables change from the PSM approach to the OLS regression. Household size is now negative, farmer education level is now positive, village location is positive and total non-rice income is now positive.

It is worth noting that in the wet season, hybrid seed choice has a dampening effect on total rice production, which is consistent with findings from the PSM approach. As well, in the dry season, the binary variable for hybrid seed choice is positive, as previously determined through the matching exercise.

By estimating a model using an OLS regression approach instead of the matching approach used in this article, it is possible to reach very different conclusions. An OLS approach may give a biased result due to self-selection bias and mismeasurement through the inclusion of the hybrid seed adoption choice variable in the regression. By using a PSM approach, we are able to control for selection bias, a prevalent problem in analyzing technological adoption due to the non-random selection of farmers. For this reason, it is necessary to have a matching approach such as PSM when performing this type of analysis. By comparing PSM results with OLS regression results, we can see that regression can yield naïve conclusions since seed choice is endogenous – inherently better farmers will have better production, regardless of seed choice; but better farmers will also be more likely to adopt hybrid seed in the first place. Biased and unreliable results derived from such a regression model will further bias any policy implications or recommendations derived from it. In order to evaluate the benefits of technology adoption in developing countries, a matching approach is more appropriate.